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USASRDL Technical Report 2094

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RESEARCH IN ATMOSPHERIC PHYSICS AT USASRDL (U)

Hans J. aufm Kampe

1 February 1960



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1 February 1960

USASRD L Technical Report 2094

RESEARCH IN ATMOSPHERIC PHYSICS AT USASRD L (U)

Hans J. aufm Kampe

DA Project Nr. 3A99-07-001

U. S. ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY

FORT MONMOUTH, N. J.

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ABSTRACT

(U) The atmosphere and its time and space variation play an increasingly important role in modern warfare. Electromagnetic waves, shells, rockets, missiles, and airplanes move through the atmosphere and are affected by it. The research in atmospheric physics being carried out in USASRD and its application to different kinds of warfare are described.

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RESEARCH IN ATMOSPHERIC PHYSICS AT USASRD (U)

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RESEARCH IN ATMOSPHERIC PHYSICS AT USASRD (U)*

INTRODUCTION

(U) From time to time people are heard to say, "Why bother with weather research? A war can't be stopped anyway because of rain, snow, or sunshine." The problem, however, is not so simple. Modern weapon systems and warfare are strongly affected by the atmosphere and its changes. Visible, infrared, and other kinds of electromagnetic radiation, as well as acoustic waves, shells, rockets, guided missiles, airplanes, etc., move through the atmosphere and are more or less influenced by it. The designers and users of modern military equipment know this very well, and the more accurate the different weapon systems, the more they are affected by the atmosphere.

(U) In order to cope with this problem, research is being carried out in the Meteorological Division of USASRD as listed in table 1. This research and some of its military applications (table 2) are discussed in this report.

Table 1. Fields of Research in Atmospheric Physics

Dynamics and thermodynamics
Radiation transfer
Aerosol, cloud, and precipitation physics
Atmospheric electricity
Upper-air physics
Mesometeorology
Weather radar research

Table 2. Some Military Applications of Atmospheric Physics Research

Battlefield surveillance
Atomic warfare
Army aviation
BRC warfare
Free rockets
Artillery
Guided missiles
Wave propagation

DISCUSSION

(U) Visual, infrared, and radar observations are very important for battlefield surveillance. At the same time they are very dependent on the status of the atmosphere. Visible light, for example, is very strongly attenuated by the particulate matter of the atmosphere called aerosol which varies with air masses, time, location, and altitude. The visibility may change from a

*This report is essentially the context of a lecture given before the Army Advisory Board on 21 April 1959

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few hundred miles to a fraction of a mile because of changes of the aerosol. Research is being carried out within USASRD to investigate size distribution, concentration, and light-scattering properties of the aerosol as functions of different weather situations and locations. Figure 2 shows the change of aerosol concentration with altitude on different days. In general, the concentration is several 10,000/cc at the ground on the continent and a few 100/cc right above the main inversion, decreasing further with increasing altitude. There are areas, however, for example in Greenland, where even at the ground the concentration of aerosol is practically zero. In these areas, human activity may be detected 25 miles and more downwind by its production of aerosol (see Fig. 3). This fact can be used for detecting military units in the arctic.

(U) While infrared radiation, as measured with the most common photoconductive cell--the lead sulfide cell, is only slightly attenuated by moderate haze, the attenuation increases with thicker haze, and clouds for these wave lengths are opaque. On the other hand, most of the present-day radar sets are not at all affected by clouds which in many cases they do not even detect. Therefore, until now, persons concerned with infrared and radar tracking had little interest in knowing what kind of clouds was present. However, research in photoconductors is rapidly advancing to a state where it is possible to penetrate some types of clouds with infrared equipment. Similarly, radar equipment, using shorter and shorter wave lengths, is approaching from the opposite end a section of the electromagnetic spectrum where the wave length is of the same order of magnitude as the droplet radii and where, therefore, the clouds begin to strongly effect propagation of infrared and radar radiation. Figure 1 shows that the most

ELECTROMAGNETIC SPECTRUM & CLOUDS

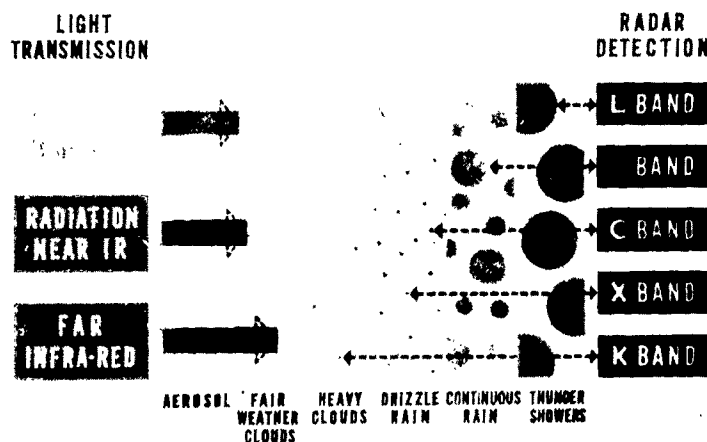


Fig. 1. The effect of aerosol, clouds, and precipitation on the transmission of visible and infrared radiation and their detectability by radar. (U)

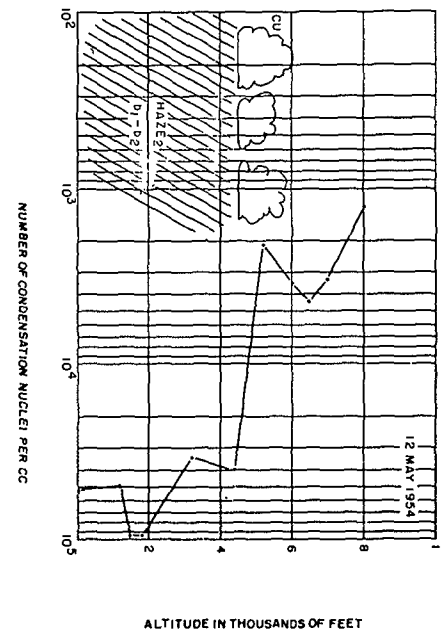
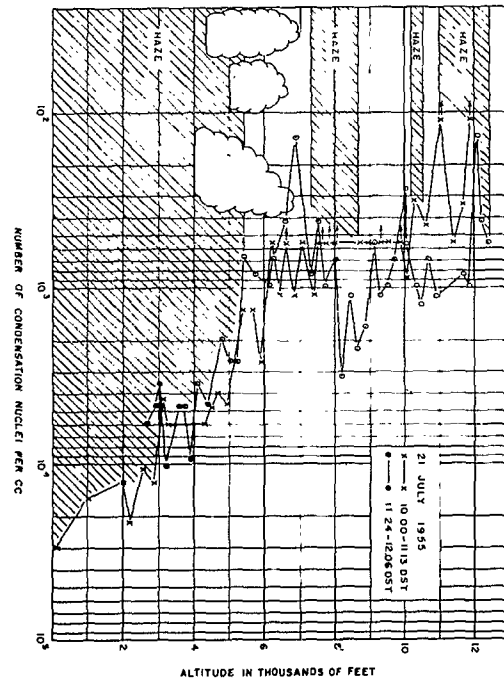
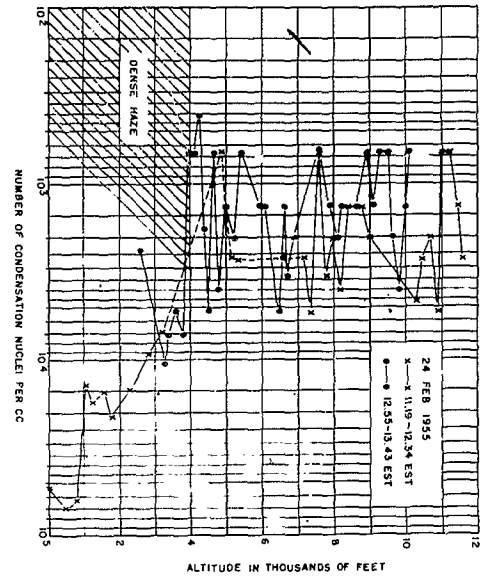
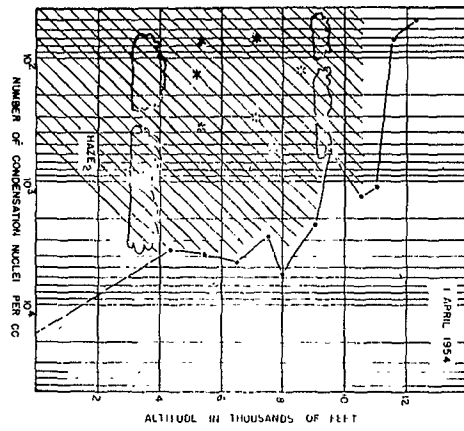


Fig. 2. Concentration of aerosol particles at different altitudes and on different days (U)

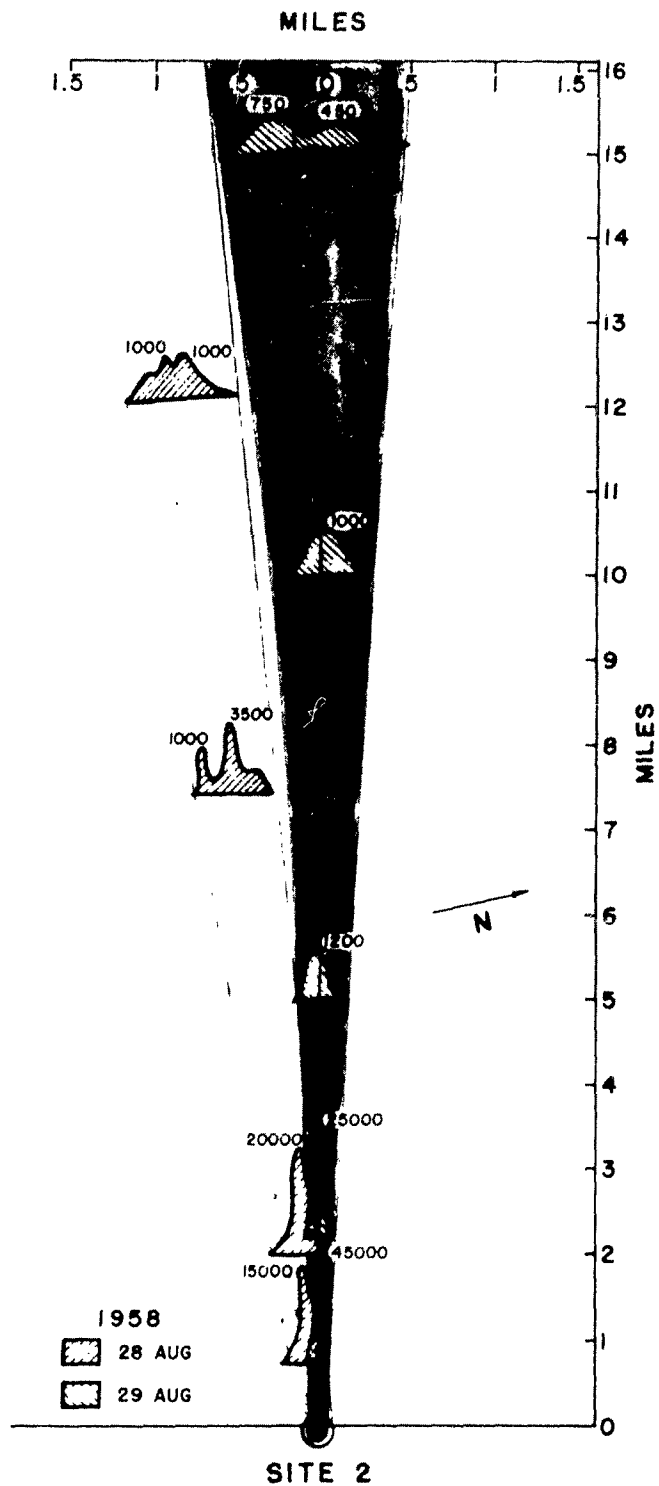


Fig. 3. Aerosol plumes produced by a camp on the Greenland ice cap. The curves indicate the aerosol concentration across the plumes, and the numbers the maximum concentration at the particular cross section. (U)

advanced infrared photoconductors begin to penetrate the clouds with the smallest droplets, whereas, on the other hand, the shortest radar wave lengths start to "see" the clouds and to be attenuated by those with the largest droplets. Because of this, the knowledge of the droplet distribution in different types of clouds is of paramount importance. In the near future investigators in the infrared and radar fields will want to know which clouds can be penetrated or detected, and how often and where their technique can be used.

(U) Visible and also infrared reconnaissance from the air--at least at the present time--cannot be carried out if a cloud deck as shown in Fig. 4 is present. Such cloud decks, rather close to the earth's



Fig. 4. A 3000-foot stratus deck 21 minutes after it was seeded with dry ice. The seeded tracks are 3 miles apart and 10 miles long. (U)

surface, often prevail for weeks over Europe and Russia during the winter. At that time of the year, however, they are frequently supercooled, and therefore several hundred square miles of cloud deck a few thousand feet thick can be dissipated with a relatively small amount of dry ice costing less than fifty dollars, as can be seen in Figs. 4, 5, and 6. It is obvious that this technique will play an important role in clearing airports and landing places for Army winged planes and helicopters as well as in the air support of ground troops. It is well known that during World War II General Rundstedt requested the German meteorological office to keep him advised of the onset of a weather situation with a low-hanging stratus deck for the start of the Battle of the Bulge in order to eliminate the support of American ground troops from the air.



Fig. 5. Same cloud deck as in Fig. 4, 30 minutes after seeding. The seeded area is 100 square miles. (U)

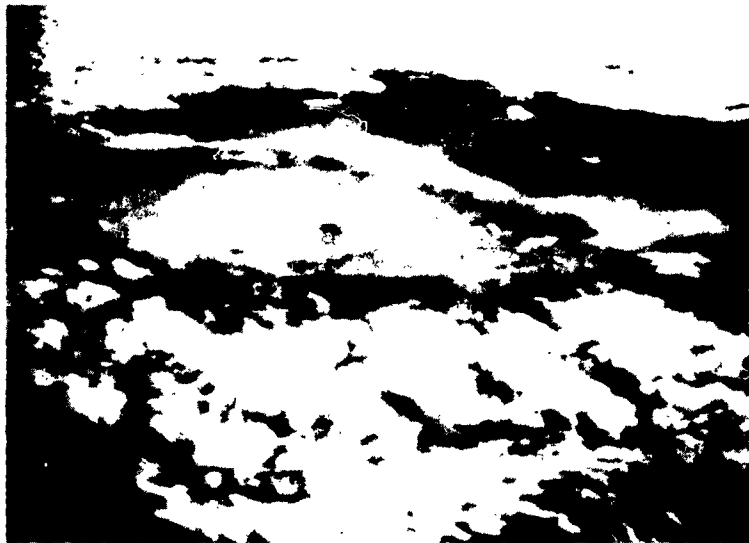


Fig. 6. Same cloud deck as in Figs. 4 and 5, 80 minutes after seeding. At that time a large ground area was clearly visible. (U)

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(U) Research in aerosol and cloud physics is also of great importance in the assessment of the heat effect of atomic explosions. It is known that the "danger radius" of an atomic explosion due to the heat effect during fair weather is roughly three times greater than that due to the blast (Fig. 7); i.e., people may not be hurt

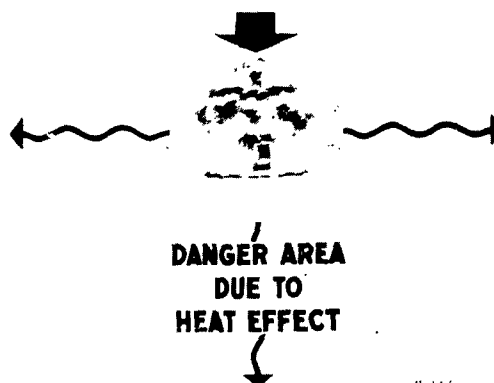


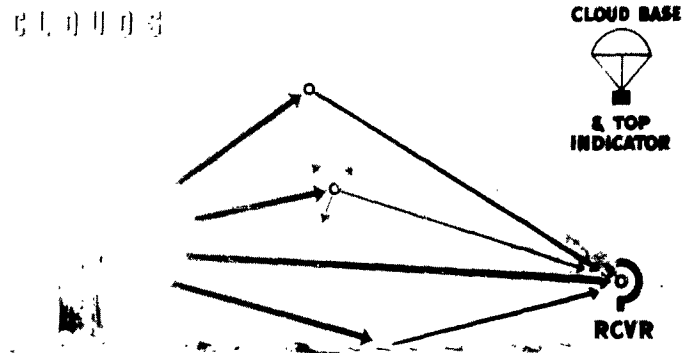
Fig. 7. The "danger area" due to the heat effect of an atomic explosion is roughly ten times larger than that due to the blast effect. (U)

at all by the blast, but be a casualty because of severe burns. The magnitude of this heat effect is greatly affected by the weather situation as can be seen in Fig. 8. The intensity of the radiation in a certain direction is very much dependent on the size and concentration of aerosol and, particularly, cloud particles. A man in a fox hole may be safe during clear weather, but badly burned if an atomic bomb were to explode below a cloud deck. On the other hand, a relatively thin cloud deck is a good shield if the explosion takes place above it. To investigate the effects of the weather on the radiation transfer, experiments are being carried out at a 400-foot-high tower where fire balls are simulated (Fig. 9). The intensity of these miniature fire balls is measured at two distances during various weather situations.

(C) Not only clouds, but also precipitation, greatly change the effect of an atomic explosion, particularly the blast effect. An average rain reduces the blast power of a 47-kt atom bomb exploded a few hundred feet aloft to less than one-tenth, as indicated in Fig. 10. This indicates how important it is to develop methods to forecast not only the occurrence of a shower but also its intensity in order to assess the effect of atomic bombs of the United States

THERMAL RADIATION...

RECEIVER RECEIVES DIRECT + REFLECTED +
PART of SCATTERED LIGHT.



M-58-413

Fig. 8. Effect of clouds and haze on the thermal radiation from an atomic explosion. (U)

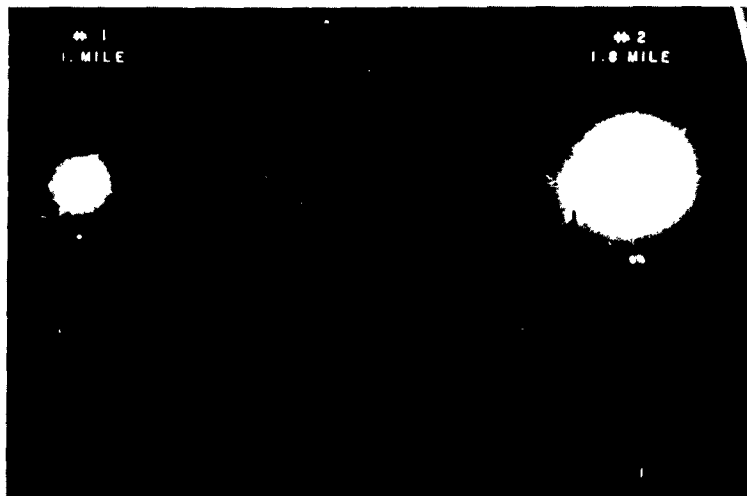


Fig. 9. The light of a simulated fireball as seen at a distance of 1 and 1.8 miles, respectively. (U)

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**REDUCTION of ATOMIC BLAST EFFECT
by PRECIPITATION**

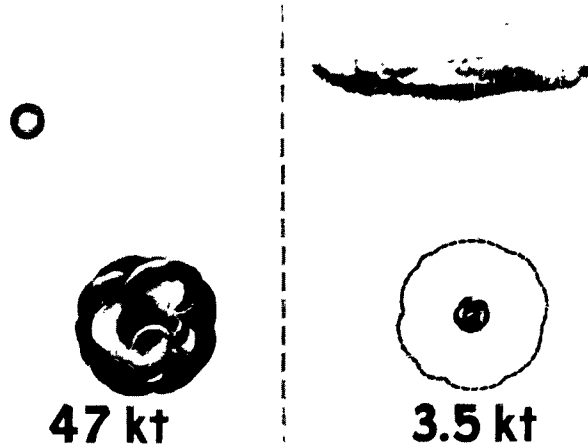


Fig. 10. The effect of rain on the super-pressure (approximately 10 pounds/square inch) produced by an atomic explosion at a certain distance (according to TM 23-200(S)). (C)

and its allies as well as those of the enemy. Mesometeorology and weather radar research are playing an important role in solving this problem.

(U) Signal Corps personnel discovered another important role of weather radar. It can detect an atomic cloud in many cases, as can be seen in Fig. 11, and track it for some time, giving for the first part of the cloud's movement the location of the radioactive cloud.

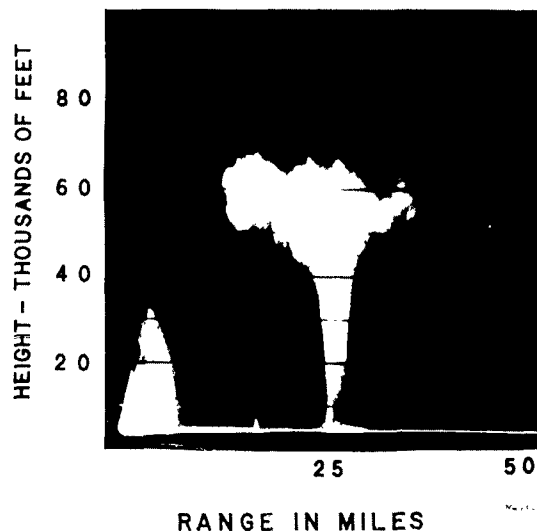


Fig. 11. Radar picture taken shortly after an atomic explosion. (U)

(U) In order to predict where the deadly radioactive dust will settle, the wind, the turbulence, the diffusion coefficient, and many other dynamic and thermodynamic properties of the atmosphere up to at least 100,000 feet must be known. These data are fed into a computer which is being developed under a Signal Corps contract. While it is hoped that this forecast will be good, it will not be perfect, and any other method of indicating the whereabouts of the radioactive clouds is welcomed. Since these radioactive clouds ionize the air, they increase the electrical conductivity of the atmosphere. This can be seen on Fig. 12 which schematically shows

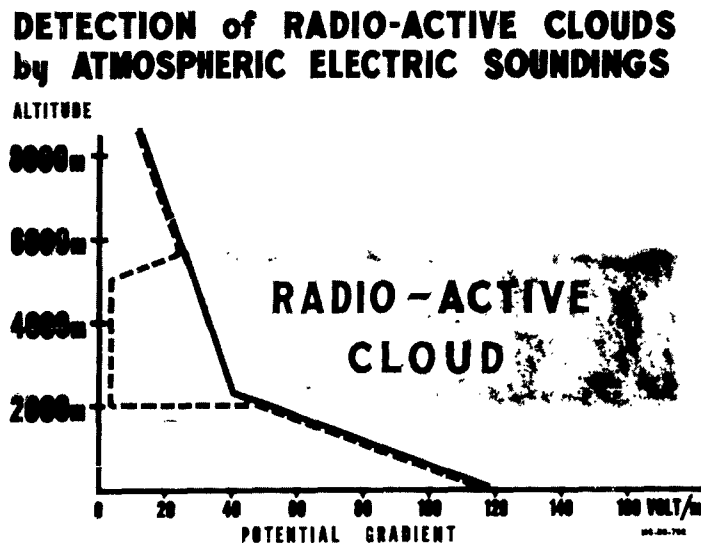


Fig. 12. Change of the normal potential gradient (solid line) due to a radioactive cloud (dashed line). (U)

how the potential gradient (solid line) decreased (dashed line) when a radioactive cloud (probably from an atomic explosion in Russia) moved over Belgium. The solid curve is typical for the variation of the potential gradient with height during fair weather. The very marked change of the gradient in the lowest few thousand feet may very well be utilized for triggering all kinds of devices when other means fail.

(U) In order to investigate the undisturbed and disturbed electric properties up to 100,000 feet and to detect radioactive clouds, an atmospheric electric attachment to the normal weather radiosonde has been developed in close cooperation with a contractor (Fig. 13). This radiosonde, on a routine basis, may systematically probe the atmosphere. It has already yielded very interesting and important results regarding the atmospheric electric parameters not only over New Jersey, but also over Greenland where the atmosphere is quite different.



Fig. 13. The atmospheric electric radiosonde (U)

SIGPM/EL-59-1589

FORT MONMOUTH, N J

AIR-EARTH CURRENT SONDE . (DEVELOPMENT)
PART OF RADIOSONDE AN/AMT-4B
BOTTOM 3/4 VIEW . SHOWING CONSTRUCTION

9 NOV 59

U S ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY

(U) Atmospheric electric research is important in another sector of atomic warfare. For the detection of atomic explosions, the electromagnetic radiation produced by the explosion is utilized and it can be quite accurately located at a distance of many hundreds of miles. However, the electromagnetic radiation from thunderstorms is similar and therefore, if thunderstorms are present in the vicinity of the recording station, the system is badly disturbed. Signal Corps research in atmospheric electricity is aimed at analyzing the wave shape of lightning discharges in order to find some characteristic differences between these and the radiation from an atomic bomb.

(U) A problem which is of great concern to the artillery as well as to the meteorologist is the low-level wind correction of the free rockets such as Honest John and Little John. From the point the rocket leaves the launcher to several hundred feet altitude, these rockets are very sensitive to the wind because of their relatively slow speed in this range. The requirements are not only to determine the wind for an instant, but to forecast the effective wind over a period of a few minutes, and over a distance of roughly 2000 feet, to an altitude of about 1000 feet with an accuracy of 1.5 miles an hour. What this means can be seen in Fig. 14. In this case

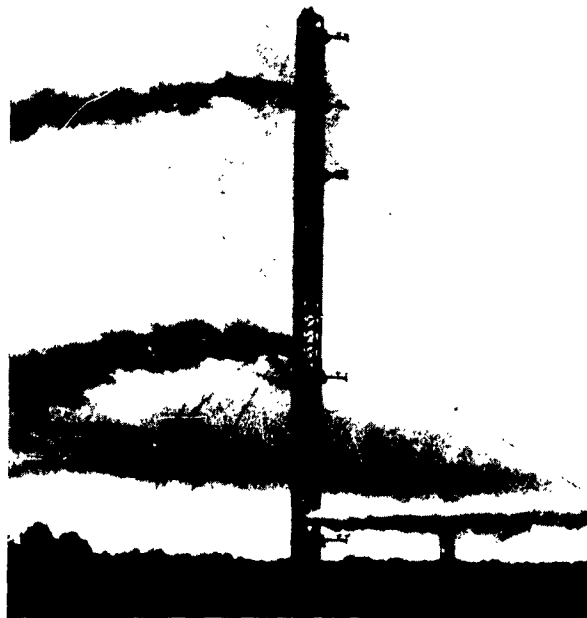


Fig. 14. Smoke trails from a 400-foot tower indicate an extremely strong wind change in the lower layer. (U)

the wind is blown from different directions with different speeds at three levels of a 400-foot tower. In order to develop a method and instruments to solve the low-level wind problem, the wind field and its variation must be thoroughly investigated. This is being done with different instrumentation and methods, utilizing among other things the forementioned 400-foot tower with its wind instrumentation (Fig. 15).

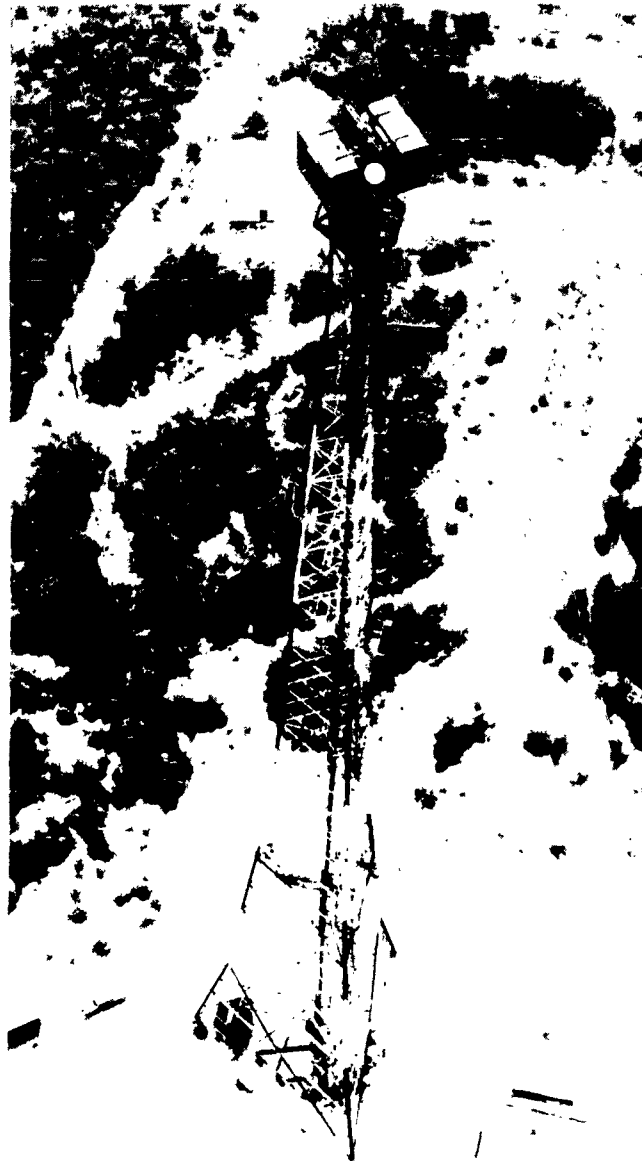


Fig. 15. Oakhurst tower (400 feet high) (U)

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(U) Table 3 shows an example of the time variability of one component. To obtain the variations of the vector wind, the figures in table 1 have to be multiplied by $\sqrt{2}$. These figures are time variations of wind speed averaged over a minute. As can be seen, they

Table 3. Mean Change in a Component Wind for Various Time Intervals in Miles per Hour (U)

Cloud Conditions	Mean Wind	Time Interval in Minutes		
		2	4	8
clear	greater than 20 mph	3.5	3.7	4.4
overcast	10 to 20 mph	2.2	2.2	2.3
clear	less than 10 mph	1.6	2.2	2.6

are quite large compared to the 1.5 miles an hour required. It should be noted that these figures present only the time variability, and that there is also a space variability. To be tactically acceptable, the instrumentation for determining the low-level wind correction must be light and relatively uncomplicated. But in making the instrumentation as accurate as possible, it will probably be bulky and complicated. Thus, the task is to find the best compromise for the optimum solution. This can be done only by continuous, extensive research into the behavior of the low-level wind field. Only this knowledge combined with an intelligent measurement can give the best result.

(U) Not only the low-level wind variability but also the variability of the large-scale wind field is of great interest because of ballistic corrections of artillery shells and rockets. The questions to be answered in this regard are how often should the Metro Section make a radiosonde flight in order to determine the wind and density structure of the atmosphere, and how should these units be spaced. Figure 16 shows the result of Signal Corps research on large-scale wind variability with time and distance which presents valuable information on the questions stated above.

(C) Very important for the ballistic correction of shells as well as for the dive phase of guided missiles like the Pershing are the absolute values of wind and density. While these values are not too difficult to obtain for artillery shells, they are quite a problem for the several-hundred-mile-range Pershing in war time where information over enemy territory, the so-called "silent area," is extremely limited. And it is still more of a problem since information up to 100,000 feet is required. The inherent probable error of the Pershing is so small that wind and density influence plays an important role. It has been repeatedly stressed by ABMA that if a meteorological correction could be worked out, many millions of dollars for designing and procuring complicated guidance systems could be saved.

(U) Research indicates that climatological data, i.e., data averaged over a long time, are very valuable for application to guidance

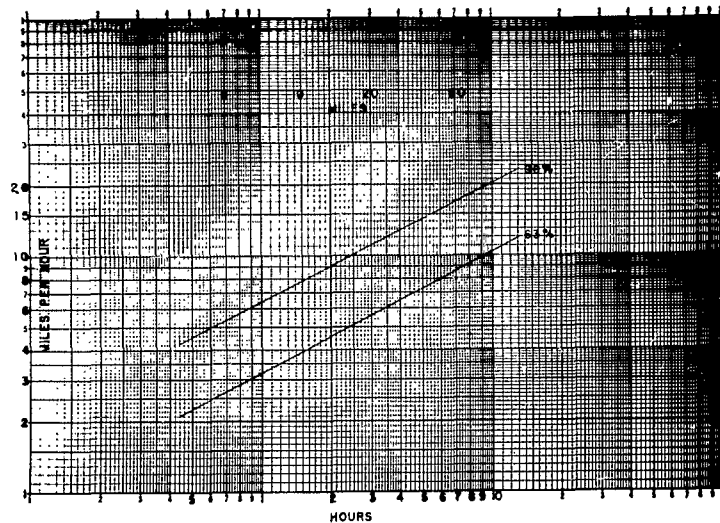


Fig. 16. Time and space variability of wind (up to 20,000 feet). The two curves give magnitude of wind variation that occurs 63 percent and 98 percent of the time. (U)

systems. Such data, however, have not been available to 100,000 feet. In order to obtain these, the Signal Corps developed special balloons and radiosondes and carried out daily flights one month of each season at eleven stations distributed over the United States, Canada, Greenland, and Panama. Figure 17 shows the distribution of these

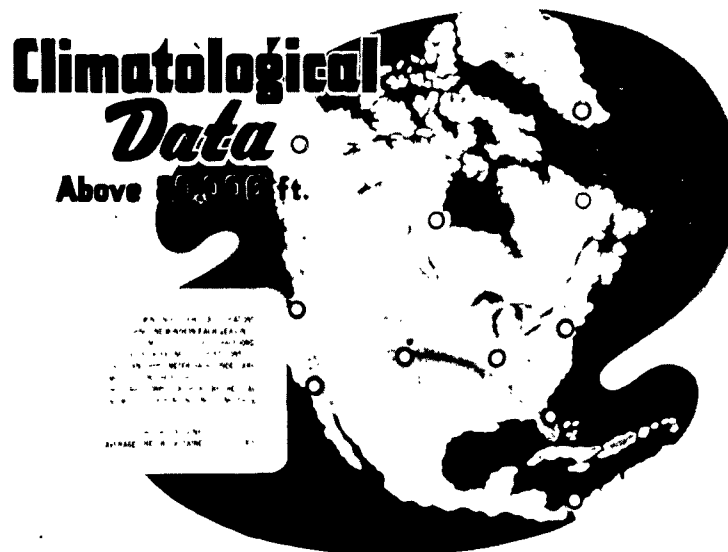


Fig. 17. High-altitude-balloon-station network. (U)

stations. In addition to climatological data, this network yielded other extremely important results. It showed, for example, that temperature changes of almost 60°C can occur within two or three days at 100,000 feet. Research personnel in the United States and abroad praised this undertaking very highly.

(U) During war time, such climatological data should be available for the entire earth, or at least for the Northern Hemisphere. Using Signal Corps data over the United States and other data from the Northern Hemisphere, although these did not reach 100,000 feet, the University of Berlin, Germany, constructed (under contract with the Signal Corps) seasonal hemispherical climatological maps for wind, density, and temperature (Fig. 18). In a recent joint Army, Air Force,

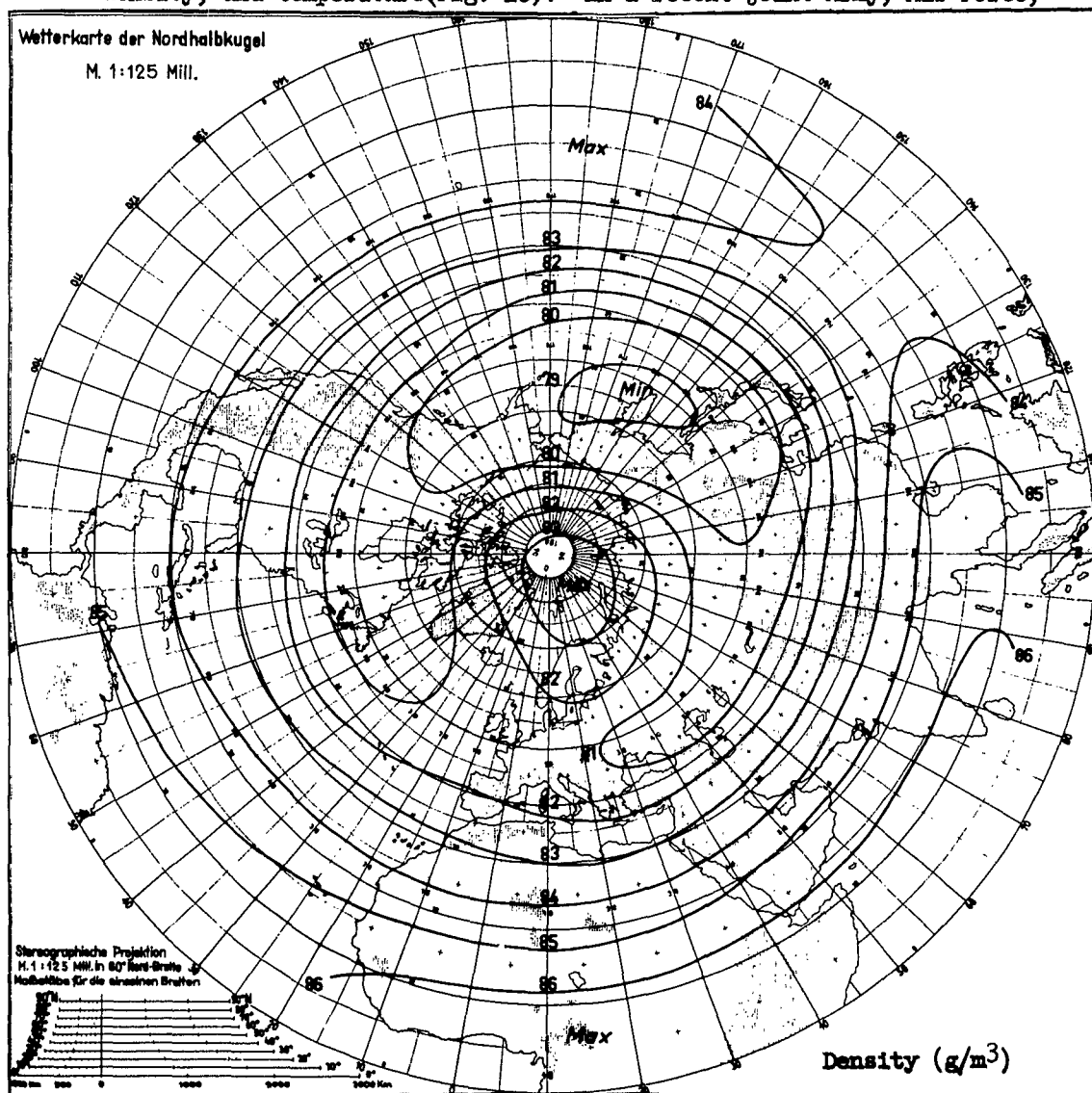


Fig. 18. Winter-density pattern at 50 mb over the Northern Hemisphere (U)

and Navy meeting on missile climatology, these maps were described as the best material presently available for high-altitude missile climatology.

(U) In the dive phase the missiles are not only affected by wind and density but also (as Fig. 19 shows) by hydrometeors such as rain,



Fig. 19. Rain and cloud erosion on a missile nose cone. (U)

ice crystals, and hail which can produce great damage to and possible disintegration of the missile. As can be seen, the forecast of such phenomena in enemy territory several hundred miles behind the front lines and its application to tactical use of missiles are other great tasks for meteorological research.

(U) While the tactical user of missiles is content with data up to about 100,000 feet, the designer of the missile and guidance systems needs more. To assure the optimum design he needs atmospheric data on wind, wind shear, turbulence, and density to altitudes of 100 km and even higher. To supply these data is another important task of the atmospheric physicist. In order to comply with these requirements, research rockets must be employed.

(U) The Signal Corps has been active for some time in the exploration of the atmosphere with research rockets. How fertile such research is can be seen on Fig. 20. It shows the NACA standard atmosphere used until recently for missile design data and based on indirect data together with the temperature-height curve obtained by the Signal Corps rocket-grenade technique. This technique consists of ejecting small grenades along the rocket path and measuring at the ground the time of arrival and angle of incidence of the sound wave. While the designer wants temperature measurements accurate to approximately $\pm 2^{\circ}\text{C}$, this temperature difference is

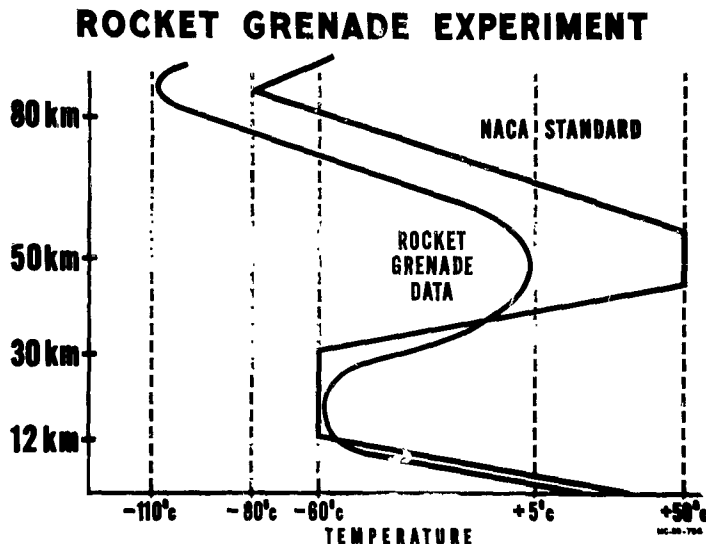
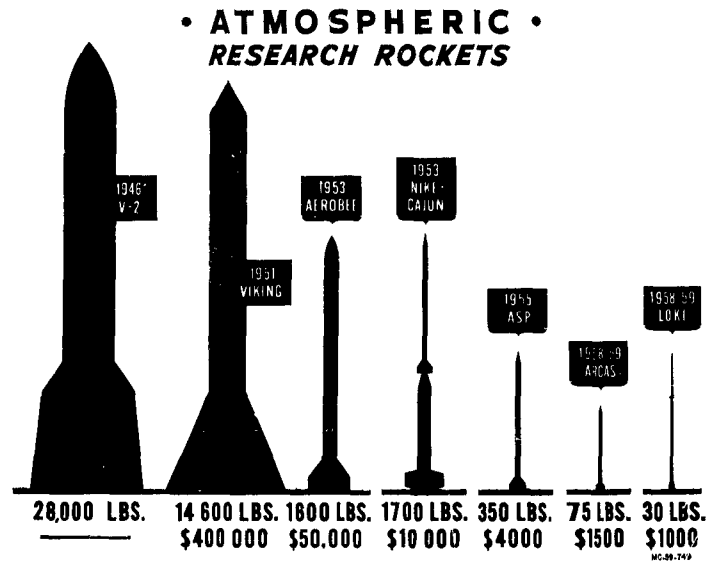


Fig. 20. Comparison of the temperature data obtained with the rocket-grenade experiment and the NACA standard atmosphere used until recently by missile designers. (U)

almost 50°C as can be seen on Fig. 20. Wind data were completely missing before the rocket-grenade method was completed. An equally important result of these firings is the discovery that while there is apparently no appreciable difference in density between summer and winter over White Sands, the summer density over Churchill, Canada, is nearly twice as high as the winter density. Other firings made over Guam are not yet evaluated.

(U) Although these data are extremely important, it must be realized that they are based on relatively few measurements. The reason for this is that the rockets with which these measurements were made are very expensive and bulky. A really valuable picture of the upper-air wind and temperature field can be obtained only by synoptic measurements of a network of stations as has been done with balloons. For these synoptic measurements, of course, small, inexpensive rockets are needed. Figure 21 shows the trend in the design of research rockets. They have become smaller and smaller within the past twelve years.

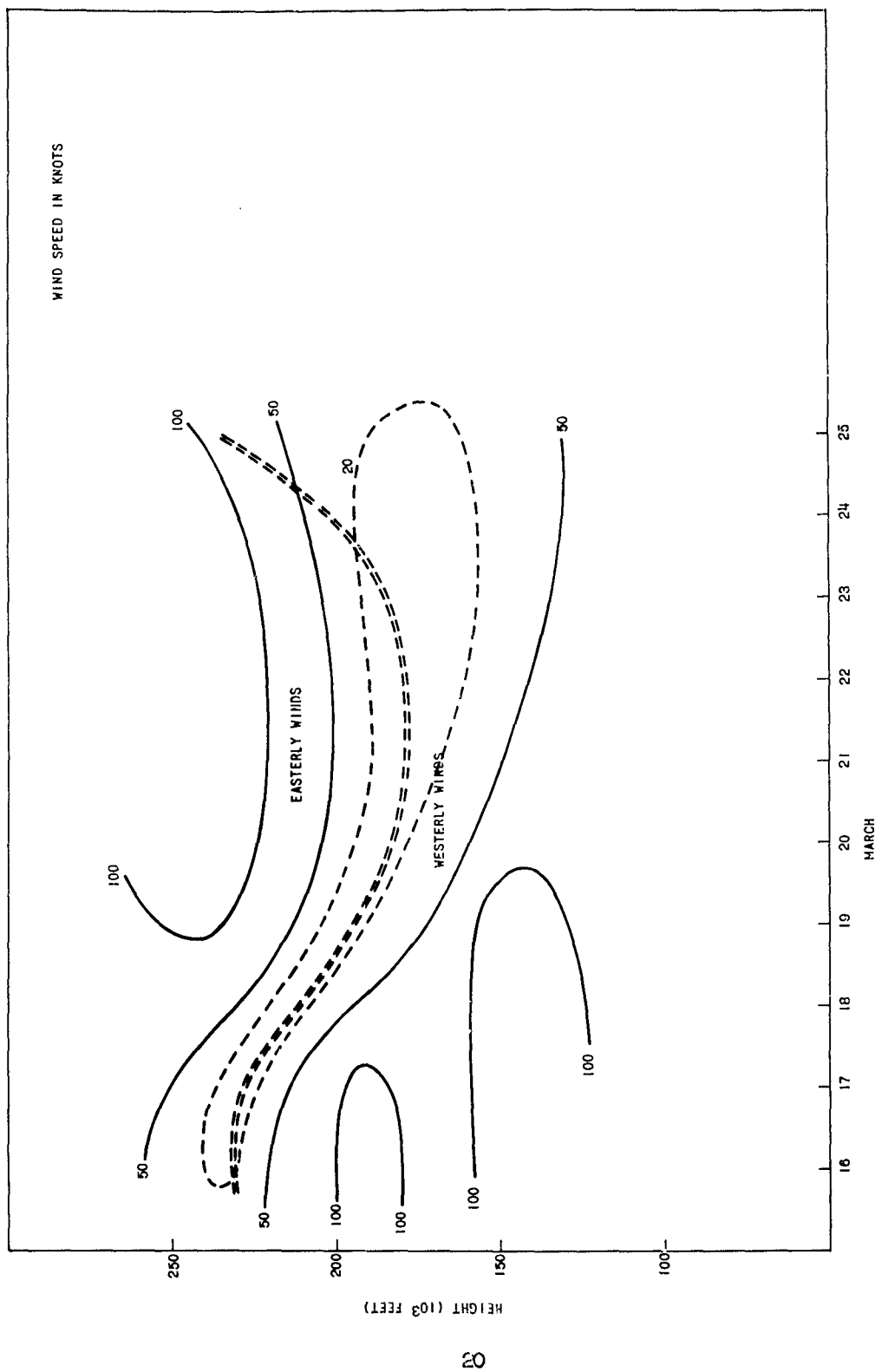
(U) Since among the atmospheric parameters the wind field is the most important one for missile design and application, the Signal Corps in a pioneering effort has employed the Loki rockets (Fig. 22) for wind measurements up to 280,000 feet by ejecting chaff and tracking it with radar. Figure 23 shows the wind pattern over White Sands Missile Range from about 150,000 to 250,000 feet over a period of several days. It is the first time in the history of meteorology that this kind of data has been obtained.



21. The trend in the design of rockets for atmospheric research. (U)



Fig. 22. The Loki rocket, weighing 29 pounds. (U)



WIND MEASUREMENTS WITH LOKI-CHAFF - WHITE SANDS, N.M. - 16-25 MARCH 1959

Fig. 23. Wind pattern as obtained by Loki rockets (U)

(U) That there are occurrences in higher regions of the atmosphere which were never suspected seems to be indicated in Fig. 24.

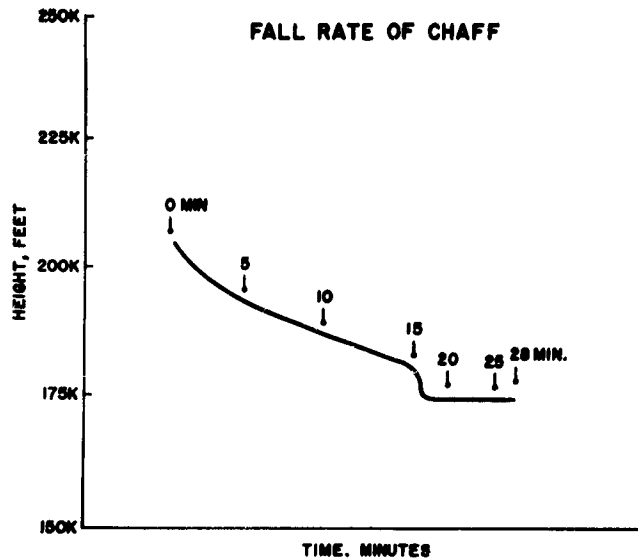


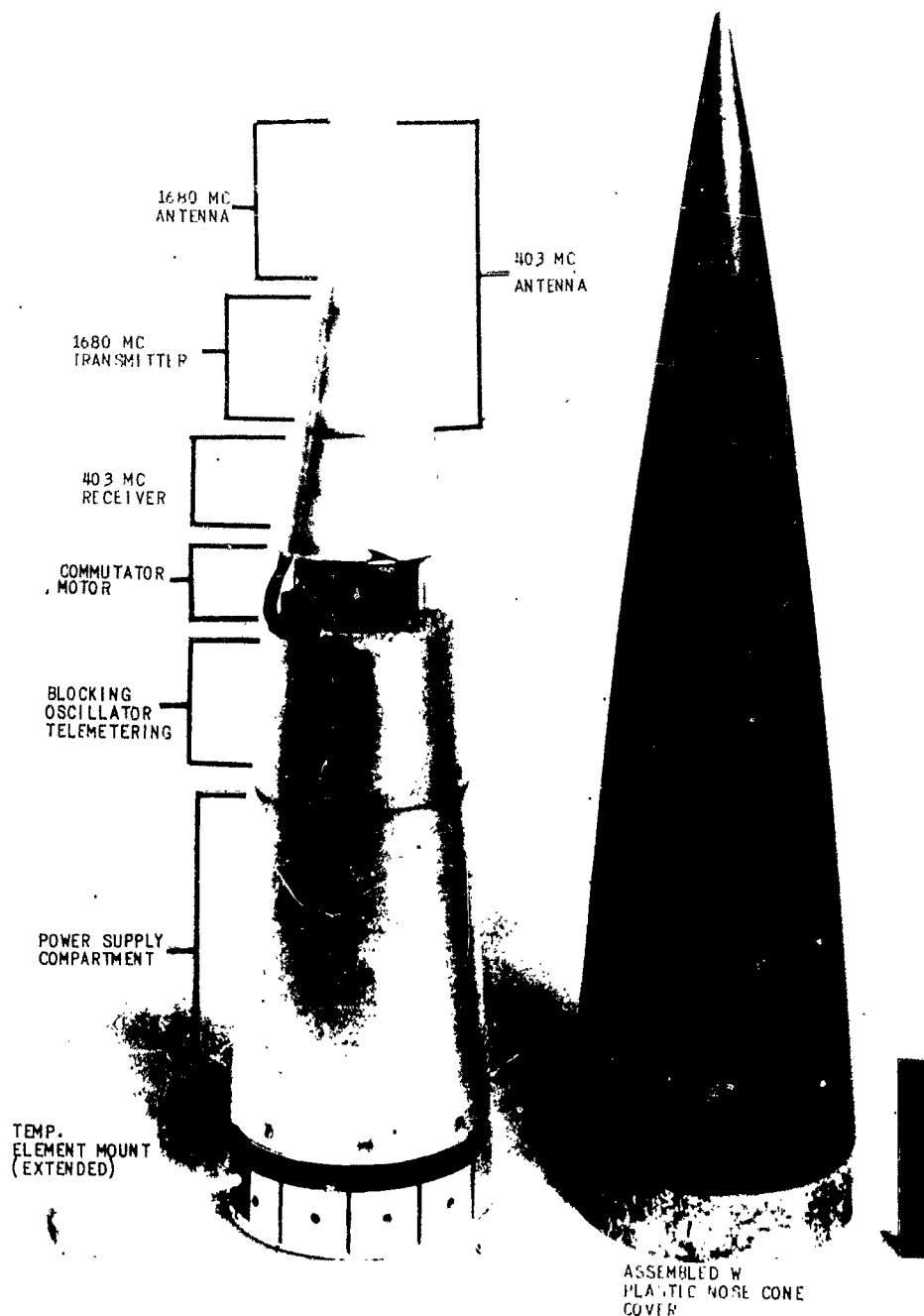
Fig. 24. Radar record of a chaff cloud ejected by a Loki rocket. (U)

It shows that the chaff cloud apparently floated for ten minutes at 170,000 feet, which would mean an extended updraft of several meters a second. This fact warrants close attention although no firm conclusions can be drawn from one case.

(U) The first results with the Loki were so encouraging that the Signal Corps suggested a synoptic network of rocket stations in the United States and Canada and possibly a station in Europe to carry out daily wind measurements during one month of each season. This should be a joint effort of the Army, Air Force, Navy, NASA, and the Weather Bureau. These agencies have enthusiastically endorsed the suggestion which, if implemented, will start a new era of upper-air meteorology and research.

(U) In order to replace the network which measures only the wind with one which will also measure temperature, the Signal Corps has developed the first meteorological rocket sonde (Fig. 25) which, in a few weeks, will make its first test flight in an Arcas rocket which was developed under contract by the Navy and the Air Force, with the Signal Corps acting in a consulting capacity. Instrumentation for measuring density and pressure in addition to temperature and wind is being developed under a Signal Corps contract.

(U) Wave propagation is a field in which the Signal Corps is, of course, particularly interested. The propagation of microwaves beyond the horizon and radio waves over many thousands of miles is strongly



SIGFM/EL-59-654

Fig. 25. Meteorological rocket sonde. (U) FORT MONMOUTH, N. J.

RADIOSONDE SET AN/DMQ-6 . (LAB. DESIGN.-CONSTR.)
 PART OF ARCAS ROCKET . USED WITH RAWIN SET AN/GMD-2
 OVERALL VIEW . SHOWING INSTRUMENTATION

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influenced by atmospheric properties. The microwave tropospheric scattering is apparently caused by inhomogeneties in the upper troposphere because of turbulence. The Signal Corps therefore has a program of measuring the turbulence not only in the troposphere but also in the stratosphere.

CONCLUSION

Although very encouraging progress is being made in the field of meteorology and upper-air physics within the Signal Corps, the research is badly lagging the requirements of the different Army agencies. This gap will become larger and larger unless the research effort is greatly increased--personnel- and money-wise.

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